Attentional Bias to Food Cues in Youth with Loss of Control Eating

by

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ABSTRACT

Attentional Bias to Food Cues in Youth with Loss of Control Eating

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Emerging data indicate that adults with binge eating may exhibit an attentional bias toward highly palatable foods, which may promote obesogenic eating patterns and excess weight gain. However, it is unknown to what extent youth with loss of control (LOC) eating display a similar bias. We therefore studied 76 youth (14.5±2.3y; 86.8% female; BMI-z 1.7±0.73) with (*n*=47) and without (*n*=29) reported LOC eating. Following a breakfast to reduce hunger, youth participated in a computerized visual probe task of sustained attention that assessed reaction time to pairs of pictures consisting of high palatable foods, low palatable foods, and neutral household objects. Although sustained attentional bias did not differ by LOC eating presence and was unrelated to body weight, a two-way interaction between BMI-z and LOC eating was observed (p = .01), such that only among youth with LOC eating, attentional bias toward high palatable foods versus neutral objects was positively associated with BMI-z. These findings suggest that LOC eating and body weight interact in their association with attentional bias to highly

palatable foods cues, and may partially explain the mixed literature linking attentional bias to food cues with excess body weight.

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CHAPTER 1: INTRODUCTION

OBESITY

Obesity is prevalent in the United States. For adults, obesity is defined as a body mass index (BMI) greater than or equal to 30 kg/m^2, while overweight is defined as a BMI between 25 and 29.9 kg/m^2 (60). National estimates from 2011-2012 indicate that more than two-thirds of adults in the United States were overweight or obese, with 34.9% meeting criteria for obesity (60). Additionally, without intervention on a policy or individual level, forecasts suggest that the obesity prevalence will increase by 33% over the next two decades (21).

Obesity is associated with increased risk of diabetes mellitus, dyslipidemia, heart disease, hypertension, cerebrovascular disease, respiratory diseases, osteoarthritis, and certain cancers (16; 48). It is estimated that in 2008, the annual medical cost of obesity in the United States was $147 billion (22). If the projected prevalence of obesity manifests as forecasted, obesity-related medical expenditures over the next two decades would increase an estimated $549.5 billion (21).

The etiology of obesity is multifactorial. Obesity results from a combination of genetic, biological, and environmental factors; however, the relative contribution of any individual risk factor is small to moderate (18; 30; 37; 50). Intentional weight loss is associated with significant health improvements (16). However, while some behavioral and pharmacologic weight loss treatments demonstrate short-term improvements in weight, bariatric surgery is the only treatment that has demonstrated maintained improvements in weight over time (16; 18; 64).

The generally poor results from weight loss treatment or maintenance are likely due to the "one size fits all" approach to weight management. Indeed, the development and maintenance of obesity is likely the result of several different phenotypes. Since most obesity studies do not differentiate between phenotypes, results are often confounded (18). As a result, there has been increasing emphasis on identifying subtypes of obesity; for example, those with low responsiveness to internal satiety signals or high responsiveness to external food cues (18). The development of phenotypes will likely help to elucidate the etiology of obesity. Additionally, targeting treatments to specific subtypes should increase treatment efficacy (18). Therefore, it is important to understand factors promoting excess body weight within obesity-prone phenotypes.

ATTENTIONAL BIAS TO FOOD CUES AND OBESITY

One factor promoting obesity may be an attentional bias to food cues that leads to excess energy intake. An attentional bias to food cues is a biased processing of food-related stimuli, which may result from a heightened salience of food cues in the environment (4; 57). In line with incentive-sensitization theory (65), the repeated exposure of a rewarding stimulus produces an exacerbated reward response in susceptible individuals with underlying biological vulnerabilities. As a result, increased salience and strong motivational properties are established for the stimulus (65). As the incentive salience of palatable food cues increases, seeking out and consuming palatable foods becomes an important goal, exceeding homeostatic feeding drives (4). It has been proposed that an attentional bias to palatable food cues represents a vulnerability to overeat in the current obesogenic food environment, consequently promoting or maintaining obesity (8; 11; 57; 58).

Past research suggests that most individuals experience an attentional bias towards food cues, particularly images of food (23; 51). However, some data suggest that overweight and obese individuals demonstrate a unique approach-avoidance pattern to palatable food cues (58; 100), indicated by increased automatic orientation to palatable food cues followed by decreased sustained attention, relative to healthy weight individuals. For example, one study using eye tracking showed that overweight participants were more likely to direct their first gaze toward food pictures, a measure of automatic orientation, compared to healthy weight participants. However, overweight participants were less likely to maintain their gaze on these pictures compared to healthy weight participants (100). This pattern may reflect the competing influences of enhanced salience of food stimuli and attempts to control behavioral responses through avoidance (57; 58).

However, not all data (e.g. 24; 28; 47) support the approach-avoidance pattern. Several studies have shown no differences in cognitive or attentional biases to food cues between overweight or obese individuals and healthy weight controls (23; 51). Additionally, one study showed no difference in automatic orientation or sustained attention to high-calorie foods between overweight and healthy weight participants as measured by eye tracking in a free-viewing task (28). Instead, this study found that overweight participants had increased automatic orientation to low-calorie foods compared to healthy weight participants, particularly among overweight participants with high restrained eating scores (28). However, there are two important considerations when interpreting these results. First, this study did not control for hunger. Second, participants

were aware that eye tracking was occurring, and therefore, social desirability among overweight participants may have affected results (28).

Overall, findings relating attentional bias to food cues and obesity have been contradictory (98). Inconsistent results in overweight samples may be due methodological issues (57), such as the specific task used to measure attentional bias (58). Alternatively, inconsistent results may be due to the heterogeneous etiology of obesity, highlighting the importance of identifying specific phenotypes within individuals prone to obesity (18). Indeed, data in adults suggest that attentional bias to food cues is associated with state characteristics such as hunger level and negative affect (24; 31; 46; 58; 92), as well as stable traits such as an increased tendency toward external eating and food-specific cravings, impulsivity, and reward drive (9; 34; 55; 92; 99; 100). Notably, many of these characteristics are reported by adults with binge eating disorder (BED; 20; 62; 68; 69), which is robustly associated with obesity (5; 103).

BINGE EATING DISORDER

Binge eating disorder (BED) is characterized by recurrent episodes of binge eating, in which individuals consume an objectively large amount of food while experiencing a sense of lack of control over eating (1). Additionally, the binge eating episodes must be associated with at least three of the following symptoms: eating rapidly, eating until feeling uncomfortably full, eating large amounts of food when not hungry, eating alone due to embarrassment, and feeling disgusted, depressed or guilty after the binge episode (1). Lastly, the individual must feel distress regarding binge eating, and binge eating episodes must occur an average of once a week for 3 months (1).

BED occurs in individuals across the weight spectrum; however, BED is most frequently observed in overweight and obese treatment-seeking individuals (1). The most common eating disorder in adults (36), the twelve-month prevalence of BED is approximately 1.6% in females and 0.8% in males (1; 75). The onset of BED is typically in late adolescence or young adulthood (1; 49). Compared to weight-matched individuals, obese individuals with BED have greater functional impairment, report lower quality of life and life satisfaction, have more concerns about body/shape and weight, and have greater psychiatric comorbidity (1; 78). The most common comorbidities are depressive disorders, bipolar disorders, anxiety disorders, and substance use disorders (1; 39). BED is also associated with increased body fat, weight gain, the development of obesity, metabolic syndrome, and increased health care utilization (1; 5; 35; 75; 103).

The etiology of BED is multifactorial and includes biological, psychological, and environmental factors (96). BED appears to be moderately heritable, with familial and genetic influences (1; 94-96). Additionally, identified risk factors for the development of binge eating include pressure to be thin, elevated rates of dieting, body dissatisfaction, depressive symptoms, emotional eating, body mass index, adverse experiences in childhood, low self-esteem, and low social support (49; 80). Several theories have been proposed to explain the development and maintenance of binge eating. For example, the emotion regulation model suggests that individuals who have difficulty regulating negative emotions use binge eating to cope with negative mood (45), while the learning model of binge eating states that binge episodes occur in response to cue reactivity and conditioned responses to food cues (38).

Individuals with BED appear to have several characteristics that may place them at increased risk for the development and maintenance of binge eating. BED is associated with more emotional eating, external eating, and food-related cravings compared to individuals without BED (56; 62). Additionally, individuals with BED report higher levels of perceived stress (62) and may have a greater physiological stress response (96). Neuroimaging studies suggest that individuals with BED have diminished activation of regions relating to impulse control and self-regulation (96). Similarly, behavioral studies show that individuals with BED may have increased impulsivity, reward sensitivity, and difficulties with inhibition, particularly with food-related stimuli (29; 68-70). Therefore, it has been theorized that individuals with BED may have increased attentional bias to food cues.

ATTENTIONAL BIAS TO FOOD CUES AND BINGE EATING DISORDER

Several studies have examined the cognitive processing of food cues in adults with BED using modified tasks such as the Stroop task, the stop signal task, and the *n*-back task (e.g. 2; 13; 51). A recent study examined inhibitory control in individuals with BED compared to individuals without BED using a stop signal task with food and neutral stimuli (82). On the stop signal task, individuals with BED were overall slower to inhibit responses, but there was no interaction with type of stimuli for response time. However, individuals with BED committed more commission errors on trials with food stimuli compared to individuals without BED. While food-specific differences were only found using one of the two tasks, these findings suggest that compared to individuals without BED, individuals with BED may have difficulty inhibiting responses, particularly when elicited by food stimuli (82). Similar difficulties in cognitive interference were found for

individuals with BED using an *n*-back task, as well as for food-specific cognitive interference as measured by the recent probes task, compared to individuals without BED (83).

However, few studies have directly examined attentional bias to food cues in adults with BED using methods such as a spatial cueing task, a visual probe task, or electroencephalography (EEG). One study examined attentional bias to food cues using EEG recordings in overweight individuals with BED compared to healthy controls (84). Differences emerged when viewing high palatable food only; women with BED demonstrated an EEG response pattern that suggested that palatable food stimuli consumed greater attentional resources (84). However, these findings were potentially confounded because BMI was not accounted for in the analyses (84).

One study examined attentional bias to food cues using two cognitive tasks (a clarification task and a spatial cueing paradigm) in adults with BED compared to a weight-matched control group (71). Results suggested that individuals with BED demonstrated an increased automatic orientation bias towards food cues compared to the control group; however, both groups demonstrated a bias in sustained attention toward food cues (71). A second study, using a free exploration paradigm, found that overweight and obese individuals with BED gazed longer on food stimuli compared to overweight and obese individuals without BED and normal weight controls (69). Overall, while paradigms varied across studies and some findings were conflicting, these studies provide preliminary evidence that adults with BED may have differential attentional bias to food cues compared to adults without the disorder.

LOSS OF CONTROL EATING IN YOUTH

Children and adolescents rarely meet the full criteria for BED (26; 32; 79; 87; 91). However, reports of episodes of loss of control (LOC) eating are common, particularly among those prone to excess weight (73; 87). LOC is the perceived inability to abstain from eating or to stop eating once begun (1). The subjective experience of LOC may be a more salient indicator than episode size when describing aberrant eating in pediatric samples (27; 49; 72; 97). In one study, youth who reported objectively large binge episodes did not differ significantly from youth with only subjectively large binge episodes on disordered eating attitudes, emotional eating, eating in the absence of hunger, depressive symptoms, anxiety symptoms, or adiposity (72). However, both groups differed significantly on these variables compared to youth who reported only overeating episodes, without the experience of LOC, as well as to youth who reported no eating episodes (72). Additionally, while a "large amount of food" is required to meet criteria for a binge episode, determining this threshold can be difficult in growing children of different ages and sex (87).

Notably, youth with LOC eating appear to have an increased preference for highly palatable foods. Data collected from self-report measures (93) and in the laboratory (88), indicate that youth with reported LOC eating consume more snack- and dessert-type foods, as well as more energy from carbohydrates and less from protein compared to youth without LOC eating (88; 93). These data support the notion that youth with LOC eating may be particularly susceptible to attentional bias toward palatable food cues, which may promote the obesogenic eating patterns that distinguish the LOC phenotype.

The presence of LOC eating places youth at high risk for the development of partial or full-syndrome BED (33; 77; 89) and excessive weight and fat gain (85; 90).

While no study has examined the interaction of LOC eating and weight status on outcome variables, there is preliminary evidence that the interaction of LOC eating and weight status may impact eating behavior. One study found that while youth with LOC eating did not consume more total energy than youth without LOC eating, overweight/obese youth with LOC eating consumed more total energy at a binge meal than overweight/obese youth without LOC eating (88). This suggests that the presence of LOC eating and excess weight may interact to predict eating- and weight-related outcomes.

ATTENTIONAL BIAS TO FOOD CUES IN YOUTH

There are limited data on the cognitive processing of and attentional biases to food cues in youth. With respect to cognitive processing, overweight children appear to have more difficulty inhibiting responses towards food cues compared to lean children (54). Similarly, one study showed that obese children had increased cognitive interference for food words using a modified Stroop task compared to healthy weight children (8). However, a second study found no differences between overweight and healthy weight adolescents in attentional bias to food cues as measured by an imbedded word task (76). Only one known study has examined the relationship between weight status and attentional bias to food cues in youth. This study measured attentional bias by examining neural activity in reward and attentional processing regions during an fMRI scan. Attentional bias to food cues was not only positively correlated with BMI cross-sectionally, but also predicted increased BMI percentile gain one year later (104).

No study has examined attentional bias to food cues and LOC eating in youth. Additionally, no known study has directly examined the relationship of attentional bias to food cues and obesity in youth using a visual probe task. While a variety of attentional

bias paradigms exist, many are indirect measures, such as the modified Stroop task. Instead, the visual probe task is advantageous because varying the stimulus duration allows for the differentiation between automatic orientation and sustained attention (19), and many attentional bias modification interventions are adaptations of the visual probe task (6; 15).

THE PRESENT STUDY

Individual differences in behavioral phenotypes promoting obesity (18) may account for the heterogeneity of findings regarding attentional biases and weight status. Indeed, it is possible that the relationship between attentional biases to food cues and weight status may vary as a function of LOC eating or BED presence. Individuals with LOC eating or BED, who have been shown to be more impulsive and sensitive to the rewarding properties of palatable foods relative to weight-matched controls (20; 68), may experience greater difficulties with diverting attention from foods regardless of their goals. Such sustained attention towards palatable foods may be associated with exacerbated cravings (41) that trigger LOC episodes and frequent overconsumption, which may promote excessive weight gain and obesity. By contrast, it is possible that overweight youth without LOC eating exhibit the approach-avoidance bias pattern, as they may possess improved attentional control capacity in the face of palatable food cues relative to those with LOC eating. However, these hypotheses require empirical evaluation.

Therefore, the objective of this study was to examine biases in sustained attention toward high palatable foods using a visual probe task in youth with and without reported LOC eating. Due to the lack of previous research examining the interaction of LOC

eating and weight status, we also examined whether this interaction was related to attentional bias to high palatable foods. This interaction would indicate if LOC eating represents a specific subtype of obesity that shows elevated attentional bias. Additionally, given the inconsistent prior literature in overweight and obese adults (e.g. 11; 100), we also explored whether weight status alone was related to attentional bias to high palatable foods. Lastly, in order to determine whether findings were specific to high palatable foods, we also examined biases in sustained attention toward low palatable foods.

AIMS AND HYPOTHESES

Aim 1: To examine the relationship between LOC eating status and sustained attentional bias to food cues.

Hypothesis 1a: Attentional bias to high palatable foods only, as measured by the visual probe task, will vary by LOC eating status such that youth with LOC eating will have greater sustained attentional bias to high palatable foods compared to youth without LOC eating.

Hypothesis 1b: LOC episode frequency will be significantly and positively correlated with sustained attentional bias to high palatable foods only, as measured by the visual probe task.

Aim 2: To examine whether weight status and LOC eating status interact to predict attentional bias to food cues.

Hypothesis 2. BMI-z score and LOC eating status will interact to predict sustained attentional bias to high palatable foods only, as measured by the visual probe task, such that heavier youth with LOC eating will have the highest levels of sustained attentional bias to high palatable foods.

Exploratory Aim: To examine the relationship between weight status and sustained attentional bias to food cues in youth.

CHAPTER 2: METHODS

RESEARCH DESIGN

A correlational design was used to examine attentional bias to food cues in a convenience sample of youth with and without LOC eating.

PARTICIPANTS AND RECRUITMENT

Participants were children and adolescents, aged 8-17 years, drawn from three separate studies. Two were non-intervention studies. The first, carried out at the NIH, examined eating behaviors in adolescent boys and girls (13-17 years) with and without reported LOC eating of all weight strata (ClinicalTrials.gov ID: NCT00631644). The second non-intervention study took place at USUHS and recruited overweight (BMI ≥ 85th percentile) adolescent (12-17 years) girls with reported LOC eating for a study of mood and eating behaviors. The third protocol was a prevention trial, carried out at the NIH, that included overweight and obese (BMI ≥ 85th percentile) boys and girls with LOC eating (ClinicalTrials.gov ID: NCT00263536), all of whom were studied prior to receiving any intervention. All studies excluded individuals with major medical or psychiatric disorders (other than BED), as well as individuals taking prescription medications that could affect eating and/or weight.

Participants were recruited through multiple methods: advertisements in local newspapers, referrals from physicians' offices, mailings to local area parents, flyers posted at the National Institutes of Health (NIH) and the Uniformed Services University of the Health Sciences (USUHS) in Bethesda, Maryland, and local public facilities, with

permission. Flyers were also distributed through local elementary, middle, and high school parent listservs.

Study Procedure

Across the three studies, all data were collected at participants' screening visits following an overnight fast. Height and weight were collected, and then participants consumed a breakfast meal (a breakfast shake, granola bars, or a muffin) to ensure satiety. Approximately 5 to 10 minutes after eating breakfast, youth completed a questionnaire to assess hunger and, immediately following, completed a visual probe task. For the non-intervention studies, the EDE was completed in the afternoon following the visual probe task. For the prevention study, the baseline assessments took place over two days, and the EDE was completed on a separate day from the visual probe task.

Measures

Body mass index (BMI)

Height was measured in triplicate by stadiometer and weight was measured by calibrated scale to the nearest 0.1 kg. BMI (kg/m^2) was calculated using height, averaged across the three measurements, and weight. Age and sex were included to produce a BMI-z score based on the Centers for Disease Control and Prevention growth standards (12).

Loss of control (LOC) eating

The Eating Disorder Examination (EDE) is a semi-structured interview that was used to assess LOC eating. Children were administered either the EDE Version 12.0D (17) with updates from versions 14 and 15, or the child version (10). Both the adult and child versions measure the same constructs and have been successfully combined in

previous studies (e.g. 26; 88) and have shown excellent inter-rater reliability (26; 91). LOC eating was deemed present if youth endorsed at least one objective binge episode (defined as consuming an objectively large amount of food while experiencing a lack of control over eating) or subjective binge episode (defined as consuming an ambiguously large amount of food while experiencing a lack of control over eating) within the past 28 days. The number of LOC eating episodes over the past 28 days was collected.

Hunger ratings

Following breakfast, all participants rated their level of hunger on a visual analog scale that ranged from "not at all" to "extremely" (on a scale of 0 to 100) immediately prior to participating in the visual probe task. Previous studies indicate that the visual analog scale is valid, reliable, and positively correlated with food intake (61; 81).

Attentional bias to food cues

A visual probe task was used to measure biases in sustained attention to food cues. The task consisted of 180 trials in which pairs of color photographs were presented on a HP laptop screen. The visual probe task was coded using E-Prime 2.0. The task used 90 photos from one of three categories: 30 high palatable (HP) foods, 30 low palatable (LP) foods, and 30 neutral non-food (NF) control stimuli, which consisted of emotionally neutral images of household items (e.g. paper shredder, paintbrush). Each photo was shown a total of four times. All of the food stimuli and the majority of the neutral stimuli were drawn from a previously validated database that has been used in previous studies (e.g. 74). Additional neutral items were drawn from the International Affective Pictures System (44). For the purposes of this study, energy-dense foods (i.e., foods high in fat such as pizza and donuts) were used as a proxy for "high palatable" foods. Energy-dense

foods have been shown to be more palatable and less satiating than other foods. Thus, it is likely that energy-dense foods differentially promote over-consumption of energy and the development and/or maintenance of obesity (14). Similarly, foods with low energy density (i.e., foods low in fat such as mushrooms and pineapples) were used as a proxy for “low palatable foods”.

The majority of food pictures from the database (94.3%) were validated in a sample of older adolescents and young adults by providing ratings of typicality (indicators of how typical each picture was of its respective food category) and palatability. For each picture, participants in the validation sample provided typicality ratings and appetizing scores, both rated 1 to 7 on a Likert scale, with 7 representing the most typical or appetizing. In the validation sample, the typicality of pictures was acceptable (defined as a rating of at least 5 on the Likert scale) for low palatable foods ($M = 5.28$, $SD = 0.71$), high palatable foods ($M = 5.68$, $SD = 0.46$), and neutral stimuli ($M = 5.38$, $SD = 0.76$). As expected, appetizing scores were significantly higher for high palatable foods ($M = 5.33$, $SD = 0.72$) than for low palatable foods ($M = 4.52$, $SD = 1.11$; $t(39.71) = 3.12$, $p = .003$). No additional information is available for the validation sample or for the validation of stimuli. The remaining pictures used in the task were not validated.

Across the task, trials were divided into three pairing categories: HP-LP in which a high palatable and low palatable image were paired; HP-NF in which a high palatable and neutral non-food item were paired; and LP-NF in which a low palatable and neutral non-food item were paired. Although the images varied considerably in visual features such as color and complexity, each pairing was matched to make images within pairs as

homogeneous as possible (e.g. matching on shape to pair a pizza pie with a clock), and specific pairings were maintained across all participants in the study. Fifteen such pairings were created for each category, and each pair was presented four times with the location of stimuli and probe counterbalanced as described below. The order of stimulus presentation was randomized.

For each trial, a fixation cross appeared. After the fixation cross disappeared, stimuli were presented side-by-side (2000 ms), after which both images disappeared and a probe appeared in a location previously occupied by one of the two pictures (1000 ms). The probe consisted of either a left or a right arrow, and participants were instructed to respond, as quickly and accurately as possible, with the left arrow button if pointing left, and the right arrow button if pointing right. In order to minimize automaticity, the inter-trial interval randomly fluctuated across three durations of 500ms, 1000ms, or 1500 ms. The total visual probe task duration was approximately 10 minutes (Figure 1 illustrates a visual depiction of the task).

Visual probe tasks are frequently built upon a probe position paradigm, during which participants respond based on the probe position (i.e. participants respond using a key that corresponds to whether the probe appeared on the left or the right). A potential disadvantage of this approach is that participants may adopt a biased monitoring strategy that favors either the left or the right region of the task (52). To encourage equal monitoring of the left and right regions of the task, for the present study, the visual probe task was built upon a probe classification task as in previous studies (7; 52; 59; 66; 67). Specifically, the participant was instructed to respond based upon the type of probe (i.e.,

left or right arrow) as opposed to the position of the probe. Prior to initiation of the visual probe task, participants completed a practice task (53; 58; 101) that consisted of 20 trials.

HUMAN SUBJECTS PROTECTION

The *Eunice Kennedy Shriver* National Institute of Child Health and Human Development, NIH and USUHS institutional review board approvals were obtained for each study at the respective sites. Parents and participants provided written consent and assent, respectively, for study participation.

DATA ANALYTIC APPROACH

All analyses were conducted using SPSS Version 19.0. Data were examined for outliers and screened for normality. One extreme outlier was identified across all visual probe task variables and was therefore recoded to 1.5 times the interquartile range above the 75th percentile to minimize its influence on the data analyses (3). Additionally, the number of LOC episodes in the past 28 days was log transformed for normality. The assumptions of all analyses were checked, and no assumptions were violated. Differences were considered significant when p values were $\leq .05$. All tests were two-tailed. Differences in demographics and hunger rating between LOC eating groups were examined using independent samples t-tests, chi-square tests, and Fisher's exact tests where appropriate. Lastly, race was coded as a binary variable (Non-Hispanic White = 0; Other = 1).

Attentional Bias Scores

Trials were excluded from analysis if participants failed to respond within the 1000 ms probe display window, or if the response was incorrect. An attentional bias score for sustained attention was calculated for each participant on each of the three pair types

based on reaction times. The reaction time to the more salient of the paired images was subtracted from the reaction time to the less salient image in the pair, resulting in bias scores in which higher scores represent greater bias. Faster reaction times are suggestive of a greater attentional bias towards the cue; therefore, negative attentional bias scores indicate a bias away from the salient cues, whereas positive attentional bias scores indicate a bias toward the salient cues. The attentional bias score for HP-LP pairs was generated by subtracting reaction times for high palatable food cues from reaction times for low palatable food cues; therefore, positive attentional bias scores for HP-LP pairs indicate a bias towards the HP cues. The attentional bias score for HP-NF pairs was generated by subtracting reaction times for high palatable food cues reaction times from reaction times for neutral non-food cues; therefore, positive attentional bias scores for HP-NF pairs indicate a bias towards the HP cues. Lastly, for LP-NF pairs, reaction times for low palatable food cues were subtracted from reaction times for neutral non-food cues. Therefore, positive attentional bias scores for LP-HF pairs indicate a bias towards the LP cues.

Aim 1

For each pair type, differences in attentional bias scores between youth with and without LOC eating were examined using independent samples *t*-tests, and then were repeated using one-way analysis of covariances (ANCOVAs), controlling for BMI-z score. Additionally, for each pair type, the relationship between LOC episode frequency and attentional bias scores were examined continuously within all participants using bivariate correlations, as well as using partial bivariate correlations controlling for BMI-z.

Aim 2

A general linear model was conducted with one between subjects categorical independent variable (LOC eating status: presence, absence), one between subjects continuous independent variable (BMI-z score) and one within subjects independent variable (pair type: HP-LP bias, HP-NF bias, LP-NF bias). Due to the varying inclusion criteria across the three studies, differences in demographics were expected. Therefore, we also included study (breakfast type), age, sex, and race as well as self-reported state hunger prior to the task in all analyses. All interactions were included in the model. Participants who did not have a valid hunger rating (n = 4: LOC eating = 2, No LOC eating = 2) were not included in the general linear model.

For a significant three-way interaction, multiple regression analyses were conducted involving interaction terms within each pair type. For significant two-way interactions in the follow-up regression analyses, the slopes of the regression line between bias and BMI-z within each LOC eating group were analyzed using a linear regression t-test to determine if each slope significantly differed from zero. A slope of 0 would indicate that there was no relationship between attentional bias and BM-z score within the specific LOC eating group.

Exploratory Aim

For each pair type, the relationship between BMI-z and attentional bias scores were examined continuously using correlations and categorically across weight groups using one-way analysis of variances (ANOVAs). Analyses were repeated controlling for LOC eating status using partial correlations and one-way ANCOVAs. Weight groups

were defined as healthy weight (BMI-z less than 1.04), overweight (BMI-z between 1.04 and 1.64), or obese (BMI-z greater than 1.64).

CHAPTER 3: RESULTS

Seventy-seven children and adolescents participated in the visual probe task. One participant was excluded from all analyses, as this child did not properly complete the visual probe task. Therefore, data from 76 children and adolescents were analyzed.

SAMPLE CHARACTERISTICS

Youth ranged in age from 8 to 17 years, with a mean of 14.45 years (*SD* = 2.30). The majority of participants were female (86.8%) and the sample spanned a wide BMI-z range (*M* = 1.71, *SD* = 0.73, range = -0.50-2.75). The ethnic/racial breakdown was 46.1% Non-Hispanic Black, 42.1% Non-Hispanic White, 2.6% Hispanic, and 9.2% other or unknown. The mean hunger rating after breakfast was low (*M* = 26.5 on a scale of 1 to 100, *SD* = 23.1), as has similarly been reported in prior attentional bias studies (42). An average of 15.9 (8.8%) trials on the VPT were excluded per participant due to incorrect responses. Overall, participants displayed positive attentional biases for HP-NF bias (*M* = 8.41, *SD* = 36.42) and LP-NF bias (*M* = 1.71, *SD* = 34.20) and a negative attentional bias for HP-LP bias (*M* = -2.42, *SD* = 28.80). Hunger rating did not correlate with HP-NF bias [$r(70) = -.11$, $p = .34$], HP- LP bias [$r(70) = .18$, $p = .14$], or LP-NF bias [$r(70) = -.04$, $p = .74$]. Over half (61.8%) of participants reported the presence of LOC eating in the past month. For youth with LOC eating, the number of LOC episodes in the past 28 days ranged from 1 to 29 (*M* = 5.60, *SD* = 6.18).

Differences Between LOC Eating Groups

As shown in Table 1, youth with and without LOC reported eating did not differ significantly on hunger rating, $t(70) = .66$, $p = .51$, or sex distribution, $p = .73$. There were also no differences in the number of excluded trials based on LOC eating status, $t(71.58) = 1.87$, $p = .07$. Youth with LOC eating were significantly younger ($M = 13.77$, $SD = 2.41$) than youth without LOC eating [$M = 15.55$, $SD = 1.61$; $t(74) = 3.51$, $p = .001$]. Youth with LOC eating were significantly heavier ($M = 2.03$, $SD = 0.40$) than youth without LOC eating [$M = 1.19$, $SD = 0.84$; $t(74) = -5.89$, $p < .001$]. Lastly, the ethnic/racial distribution was significantly different across groups, $\chi^2 (1) = 7.67$, $p = .006$.

Results for Aim 1

Youth with and without reported LOC eating did not differ significantly on HP-LP bias [$t(74) = 1.02$, $p = .31$], HP-NF bias [$t(74) = -1.37$, $p = .17$], or LP-NF bias [$t(74) = 0.03$, $p = .98$]. When controlling for BMI-z score, youth with and without reported LOC eating still did not differ significantly on HP-LP bias [$F(1, 73) = 0.18$, $p = .68$], HP-NF bias [$F(1, 73) = 1.13$, $p = .29$], or LP-NF bias [$F(1, 73) = 0.28$, $p = .60$].

When examining the data continuously, LOC episode frequency was not significantly correlated with HP-LP bias [$r(74) = -.22$, $p = .06$] or LP-NF bias [$r(74) = .14$, $p = .23$]. However, LOC episode frequency was significantly and positively correlated with HP-NF bias, $r(74) = .24$, $p = .04$. After adjusting for BMI-z, the relationship between LOC eating frequency and HP-NF bias was attenuated, $r(73) = .22$, $p = .058$.

Results for Aim 2

The general linear model revealed no main effects for pair type [$F(2, 124) = .78$, $p = .46$] or LOC eating status [$F(1, 62) = <.001$, $p = .99$]. Additionally, there was no

interaction between pair type and LOC eating status, $F(2, 124) = .03$, $p = .98$. A significant three-way interaction between BMI-z score, LOC eating status, and pair type was observed, $F(2, 124) = 3.56$, $p = .03$, $\eta^2_p = .054$. Follow-up analyses (shown in Tables 2-4) showed the two-way interaction between BMI-z score and LOC eating status was not significant for LP-NF bias [$F(1, 62) = 2.25$, $p = .14$, $\eta^2_p = .035$] or for HP-LP bias [$F(1, 62) = 0.61$, $p = .44$, $\eta^2_p = .010$]. However, there was a significant two-way interaction between BMI-z score and LOC eating status for HP-NF bias, $F(1, 62) = 7.78$, $p = .007$, $\eta^2_p = .111$.

The interaction for HP-NF bias revealed a slight negative association between attentional bias score and BMI-z among children without LOC eating (Figure 2a), and a positive association between attentional bias score and BMI-z among participants with LOC (Figure 2b). In youth without LOC, those with higher BMI-z demonstrated a trend toward a greater bias in sustained attention away from highly palatable foods compared to neutral non-food cues, as the slope of regression line between bias and BMI-z within youth without LOC eating was negative but not significantly different from zero, $F(1,27) = 3.98$, $p = .06$, 95% CI [-21.99, 0.31]. By contrast, in participants with LOC, bias in sustained attention toward highly palatable foods increased as BMI-z increased, as the slope of the regression line between bias and BMI-z within youth with LOC eating was positive and significantly different from zero, $F(1, 45) = 4.60$, $p = .04$, 95% CI [1.88, 60.98]). No other pair type interactions were significant for attentional bias in children either with or without reported LOC eating.

RESULTS FOR EXPLORATORY AIM

BMI-z score did not significantly correlate with HP-LP bias [$r(74) = -.14$, $p = .24$], HP-NF bias [$r(74) = .10$, $p = .39$], or LP-NF bias [$r(74) = -.10$, $p = .41$]. When controlling for LOC eating status, BMI-z score still did not significantly correlate with HP-LP bias [$r(73) = -.09$, $p = .46$], HP-NF bias [$r(73) = .01$, $p = .92$], or LP-NF bias [$r(73) = -.11$, $p = .33$]. When examining attentional bias categorically by weight status, no differences were found for HP-LP bias [$F(2, 73) = .72$, $p = .49$], HP-NF bias [$F(2, 73) = 2.03$, $p = .14$], or LP-NF bias [$F(2, 73) = .31$, $p = .74$]. When examining attentional bias categorically by weight status and controlling for LOC eating status, there were still no differences for HP-LP bias [$F(2, 72) = 0.27$, $p = .77$], HP-NF bias [$F(2, 72) = 2.26$, $p = .11$], or LP-NF bias [$F(2, 72) = 0.39$, $p = .68$].

CHAPTER 4: DISCUSSION

SUMMARY AND INTERPRETATION OF STUDY FINDINGS

Using a visual probe task designed to measure sustained attention, we found that neither BMI-z nor LOC eating status was directly related to attentional bias to highly palatable foods. However, in youth with LOC eating, bias in sustained attention toward highly palatable foods increased as BMI-z increased. The opposite pattern trended towards significance among youth without LOC eating.

For high palatable food, we found no difference in attentional bias by weight status when collapsed across LOC condition. This finding contradicts the only other known study that examined attentional bias to food cues across the weight spectrum in youth, which found significant negative correlations between reaction times to food cues and BMI (104). However, this study examined automatic orientation to food cues and the

reallocation of attention to food cues (104), while our study examined biases in sustained attention. Additionally, this study (104) used fMRI to examine attentional bias to food cues during an attention network task, and did not use a reaction time *difference score* across picture types. Lastly, participants in this study fasted for 4-6 hours before the study (104), while our participants were satiated. Similarly, two studies examining cognitive interference due to food cues in obese youth yielded conflicting results. Using food words (e.g. whipped cream, bread, peach), one study found that obese children displayed cognitive interference for food words as measured by a modified Stroop task (8), while the second study found no interference for high calorie food words (e.g. pizza, cake) as measured by an imbedded word task (76).

Since attentional bias to food cues may be measured through a variety of methods, including visual probe tasks and neuroimaging (19), a potentially complicating factor is that subcomponents of attention allocation may be differentially measured across paradigms (63). For example, orienting to sensory events, detecting signals for processing, and maintaining a vigilant state are subsystems of attention. Such differences across subcomponents and methods render generalizability across studies a challenge. However, the findings of this study, in conjunction with future research, may make it possible to identify the specific attentional subcomponents implicated in adolescent LOC eating.

We did not find that sustained attentional bias to highly palatable foods in youth with LOC eating differed from those without LOC eating. However, our data support the approach-avoidance pattern to palatable food cues versus neutral non-food items (100), but only among youth without LOC eating. Consistent with this pattern, in youth without

LOC eating, as BMI-z score increased, bias in sustained attention decreased. Among youth without LOC eating, leaner youth generally had a slight or absent attentional bias toward highly palatable food cues, with attentional bias shifting increasingly away from such food cues among heavier youth. In those with LOC eating, the opposite pattern was observed; leaner youth exhibited a slight attentional bias away from highly palatable food cues, with the attentional bias shifting increasingly toward palatable food cues among heavier youth. Overall, findings indicate that heavier youth without LOC eating may be more likely to demonstrate purposeful avoidance of highly palatable food cues, whereas heavier youth with LOC eating generally may have a bias in sustained attention toward highly palatable food cues.

These findings may explain the inconsistent results between obesity and attentional bias to food cues across adult studies (57). As there was no main effect of BMI-z on attentional bias, our study lends support to the importance of understanding attentional bias across varying obesity phenotypes (18). Indeed, overweight youth with LOC eating may represent a group particularly vulnerable to sustained attentional bias toward highly palatable foods. As a bias in sustained attention toward highly palatable foods represents cognitive difficulty in disengaging attention from these foods, this may explain laboratory and self-report data showing that youth with LOC tend to consume highly palatable foods (88; 93). This possibility is supported by studies that have found that experimentally manipulating attentional bias to specific types of food cues to can produce changes in food consumption patterns (40; 42). As no effects were observed for attentional bias towards low palatable foods, youth with LOC eating may experience difficulty in disengaging solely from high palatable foods. Adults with BED may be

physiologically prone to cravings for carbohydrate-rich and palatable foods (25; 102), and analogous effects may occur in youth with LOC eating. Therefore, low palatable foods may be less rewarding for youth with LOC eating compared to high palatable foods. Alternatively, both age and study were significant covariates in the analysis comparing low palatable food versus neutral non-food stimuli. Notably, these variables were not significant in other comparisons, suggesting that both age and study source may have particular relevance for attentional biases toward low palatable foods and may explain why we did not observe significant effects for low palatable foods.

Although our data are cross-sectional, the interaction between LOC eating and BMI-z score suggests that a combination of excess body weight and the LOC phenotype could promote, or be the result of, attentional bias to highly palatable foods. According to the incentive-sensitization theory, some individuals may have underlying biological vulnerabilities that render them susceptible to the development of sensitization to a rewarding stimulus (65). Similarly, obese adults with BED display increased food-related impulsivity, which may also represent a biological vulnerability for increased attentional bias to food cues (68). Thus, it is possible that LOC eating and obesity may underlie the development of attentional bias to palatable foods. Alternatively, a particular susceptibility for attentional bias to palatable food cues may promote LOC eating and/or obesity. While past research has shown that LOC eating predicts excess weight gain (90), no prospective study has examined whether weight status itself predicts the development of LOC eating. However, within a cross-sectional sample of children with LOC eating, the majority retrospectively reported becoming overweight before LOC eating developed (86). Prospective data are required to disentangle the relationships among body weight,

LOC eating and attentional bias to highly palatable foods so that effective, highly targeted interventions for specific phenotypes may be developed.

STRENGTHS

Strengths of this study include the recruitment of racially diverse boys and girls across a wide weight stratum and the use of a structured clinical interview to assess LOC eating. Additionally, we controlled for pre-task hunger, which has been found to affect biases to palatable food (46; 58; 92). In addition, the visual probe task used in this study was a probe classification task, which encourages equal monitoring of the left and right stimuli regions to produce a more accurate measurement of attentional bias.

LIMITATIONS

Limitations include that the visual probe task relies solely on reaction time, which only captures an individual's attention allocation at the time immediately before the probe appears. Eye tracking was not used in this study, which would have allowed for greater understanding of attentional allocation throughout the entire stimuli duration. Additionally, the sample was one of convenience and combined children across multiple studies. Each study involved a different standardized breakfast and varying recruitment strategies. While we adjusted for study in all analyses and hunger levels were comparable across protocols, it is possible that other unknown aspects (e.g. social desirability) may have impacted our results. Lastly, BMI-z was unequal between groups, as all participants who reported LOC eating were overweight or obese. While a limitation, we did account for BMI-z in all analyses.

ADDITIONAL CONSIDERATIONS

There are several important considerations for interpreting the study results. First,

we measured height and fasting weight before the visual probe task. It is unknown whether collecting height and weight before the task could influence attentional bias to food cues. Second, the range of LOC episodes reported by youth varied broadly. Stronger effects may have been found with a higher frequency threshold (e.g. once weekly for the past month) to determine whether attentional biases differ between youth without LOC eating compared to those with recurrent episodes. However, a cut-off of at least one episode of LOC eating in the past month has been used in previous studies (e.g. 72; 88), provides predictive validity (89; 90), and few children endorse full-syndrome BED (73). Moreover, a benefit of using subthreshold criteria is the ability to better understand precursors to adverse outcomes.

Visual Probe Task

There are several additional considerations specifically relating to the visual probe task used in this study. First, the task stimuli were not systematically matched on features that could affect attention such as color, luminance, and contrast (43). While pictures were matched on features such as shape and color, it is possible that systematic differences existed within picture pairs on features such as color, luminance, and contrast. However, an important point is that the pairings were the same across all subjects and while this may have introduced non-semantic biases within stimulus pairs across participants, this would not differentially impact groups. Therefore, we have greater confidence that any such biases are unlikely to impact our primary results. Second, study participants represented a broad age range, which may have influenced results and increased the variability of attentional bias scores. Reaction times tend to differ as a function of age, but the use of a difference score to measure attentional bias likely

mitigates these concerns. There may be differences in attentional bias to food cues across the age range; however, it is not currently known if there are developmental differences in attentional bias to food cues. Additionally, task stimuli were not validated in children. There may be unique considerations when choosing stimuli for children, such as children's familiarity with specific foods. Lastly, low palatable foods were included in the task to determine if participants had an attentional bias to all foods or solely to high palatable foods. Foods low in energy density were chosen as "low palatable" foods; however, many individuals may regard these foods as "healthy" or "diet" foods. Therefore, it is possible that other factors, such as participant dieting status, level of restrained eating, or desire to lose weight, may have influenced attentional bias in this sample.

FUTURE DIRECTIONS

Future research should continue to explore attentional bias to food cues in youth with LOC eating by using a variety of methods, such as neuroimaging and eye tracking. Longitudinal prospective designs will elucidate developmental differences in attentional bias to food cues and help to determine the directionality of our findings. Examining participants with LOC eating across the weight spectrum and utilize weight-matched control groups (91) to better understand the overlapping and unique contribution of weight and LOC eating to attentional bias to food cues. Additionally, future research should examine whether attentional bias to low palatable foods are influenced by desire to lose weight or by eating behaviors such as dieting or restrained eating. With regard to stimuli validation, future studies should validate these stimuli in a sample of children to

ensure that these images have appropriate levels of palatability, typicality, and familiarity.

Lastly, data are needed to determine whether attentional bias modification may be an effective intervention in this population. This approach has been shown to be effective in reducing biases to highly palatable foods in primarily healthy young adults (40; 42). With regard to children, one small pediatric study found that a single laboratory session of computerized attentional bias modification relatively reduced eating in the absence of hunger among obese children compared to the control condition (6). While this finding was primarily driven by an increase in eating in the absence of hunger by children in the control condition (6), these data suggest that it may be beneficial to examine the effectiveness of an attentional bias modification intervention in overweight children who experience LOC eating.

CONCLUSION

In conclusion, among youth with LOC eating, heavier children may have a greater sustained attentional bias to highly palatable foods. It warrants testing to what extent modifying such biases is an effective approach to reducing obesity and exacerbated disordered eating in these vulnerable youth.

Table 1. Participant Characteristics By LOC Eating Status Group

	LOC eating (n = 47)	No LOC eating (n = 29)	p
Age in years, *M (SD)*	13.8 (2.4)	15.6 (1.6)	.001*
Sex, *n* (%)			.73
Male	7 (14.9%)	3 (10.3%)	
Female	40 (85.1%)	26 (89.7%)	
Race, *n* (%)			.006*
Non-Hispanic White	14 (29.8%)	18 (62.1%)	
Non-Hispanic Black	27 (57.4%)	8 (27.6%)	
Hispanic	2 (4.3%)	0 (0.0%)	
Other/Unknown	4 (8.5%)	3 (10.3%)	
BMI-z score, *M (SD)*	2.03 (0.40)	1.19 (0.84)	< .001*
Weight status, *n* (%)			
Overweight	7 (14.9%)	10 (34.5%)	< .001*
Obese	40 (85.1%)	8 (27.6%)	
Hunger Rating, *M (SD)*	25.08 (20.98)	28.78 (26.43)	.51
HP-LP bias, *M (SD)*	-5.07 (27.45)	1.86 (30.89)	.31
HP-NF bias, *M (SD)*	12.89 (41.46)	1.16 (25.34)	.17
LP-NF bias, *M (SD)*	1.63 (36.19)	1.84 (31.34)	.98
Excluded VPT trials, *M (SD)*	18.64 (22.47)	11.38 (11.26)	.07

Note: * Significant at $p < .05$. Abbreviations: LOC, loss of control; HP-LP bias, bias for high palatable foods versus low palatable foods; HP-NF bias, bias for high palatable foods versus neutral non-food stimuli; LP-NF bias, bias for low palatable foods versus neutral non-food stimuli.

Table 2. Attentional Bias, HP-NF Bias

	df	*F*	η^2_p	*p*
Study Dummy Code 1	1	2.46	.04	.12
Study Dummy Code 2	1	0.48	.008	.49
LOC Status	1	0.00	.00	>.99
Sex	1	0.62	.01	.44
Race	1	1.61	.03	.21
Age	1	0.32	.005	.58
BMI-z	1	1.83	.03	.18
Hunger Level	1	1.50	.02	.23
LOC Status * BMI-z	1	7.78	.11	.007*
Error	62			

Note: * Significant at $p < .05$.

Table 3. Attentional Bias, HP-LP Bias

	df	*F*	η^2_p	*p*
Study Dummy Code 1	1	1.92	.03	.17
Study Dummy Code 2	1	1.35	.02	.25
LOC Status	1	0.04	.85	.85
Sex	1	0.19	.003	.67
Race	1	0.10	.002	.75
Age	1	0.75	.01	.39
BMI-z	1	0.98	.02	.33
Hunger Level	1	1.85	.03	.18
LOC Status * BMI-z	1	0.61	.01	.44
Error	62			

Table 4. Attentional Bias, LP-NF Bias

	df	*F*	η^2_p	*p*
Study Dummy Code 1	1	5.26	.08	.03*
Study Dummy Code 2	1	2.56	.04	.12
LOC Status	1	.02	.00	.90
Sex	1	0.30	.005	.59
Race	1	0.13	.002	.72
Age	1	5.92	.09	.02*
BMI-z	1	.00	.00	.99
Hunger Level	1	1.13	.02	.29
LOC Status * BMI-z	1	2.25	.04	.14
Error	62			

Note: * Significant at $p < .05$.

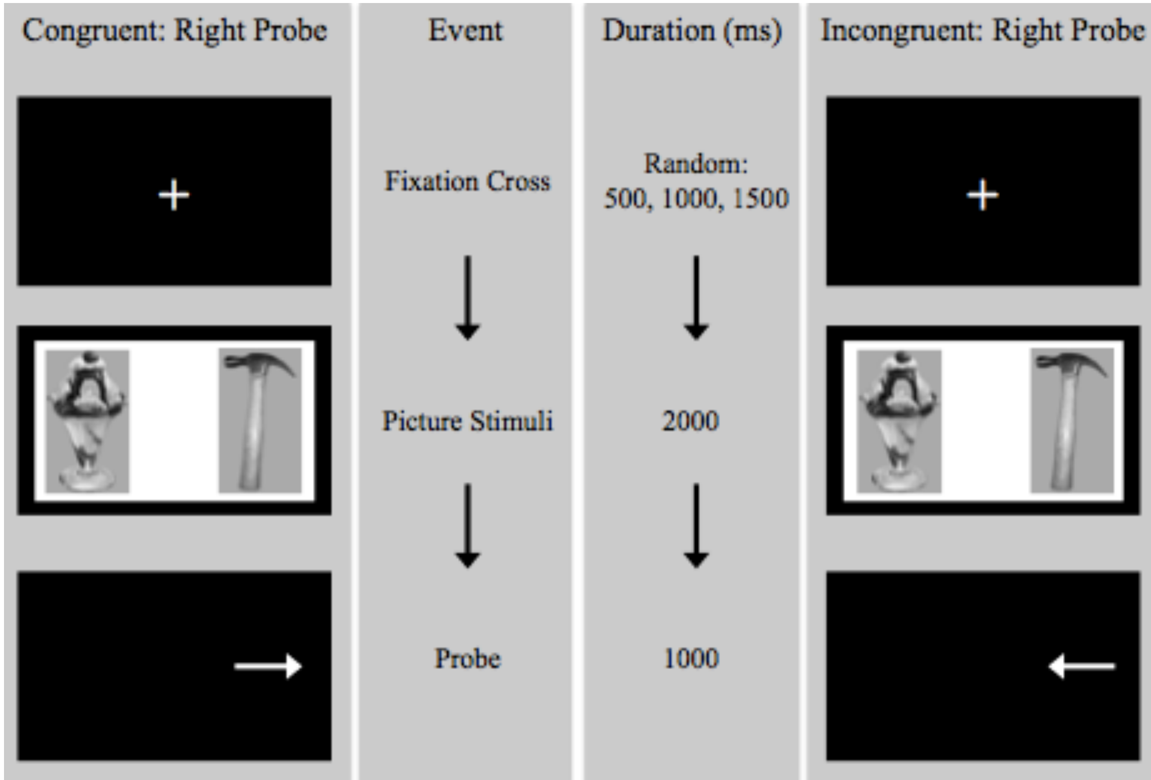


Figure 1. Visual depiction of the visual probe task.

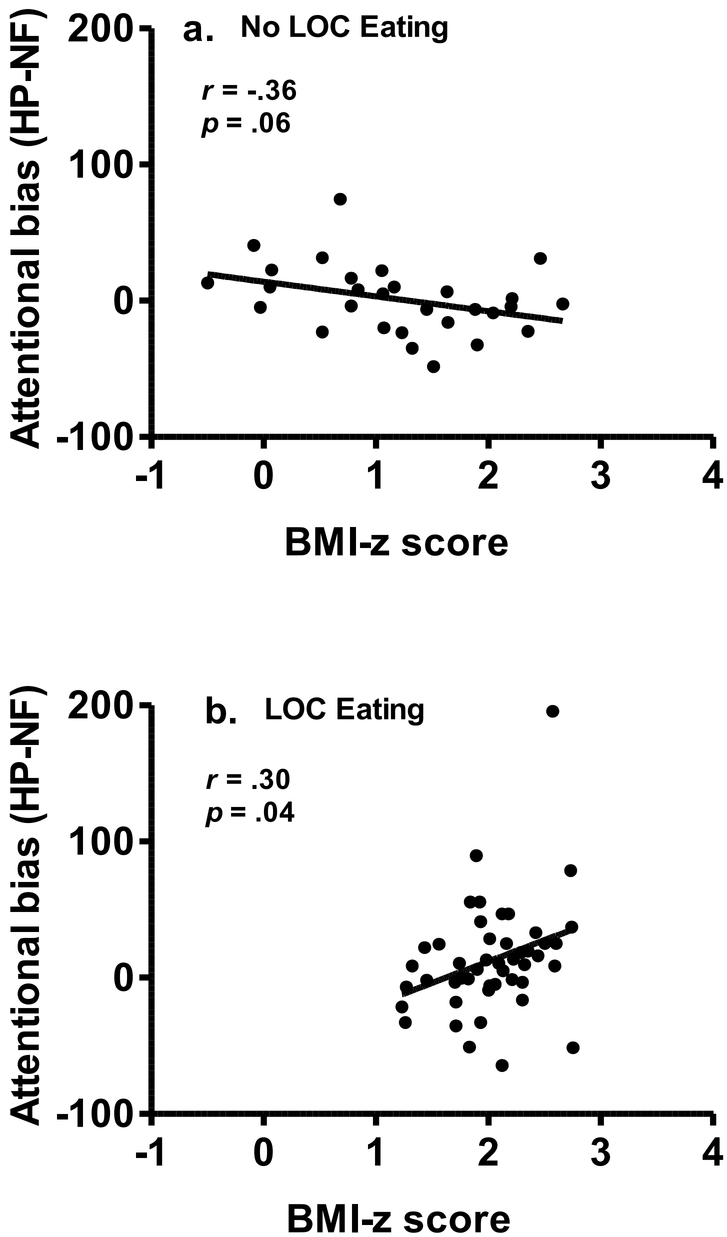


Figure 2. Interaction between loss of control eating and BMI-z for attentional bias to high palatable foods versus neutral non-food stimuli (HP-NF bias).
(A) Youth without loss of control eating have a negative association between bias in sustained attention to high palatable foods and BMI-z score, with bias in sustained attention decreasing as BMI-z increases, $r(27) = -.36, p = .06$. (B) Youth with loss of control eating have a positive association between bias in sustained attention to high palatable foods and BMI-z score, with bias in sustained attention increasing as BMI-z increases, $r(45) = .30, p = .04$.

APPENDIX A: HUNGER RATING

Study#______________ MR#____________
Interval______________ Date____________

Feelings Questionnaire

Please rate the following statements according to your appetite and how you are feeling RIGHT NOW.

For each one, draw a vertical line on the scale at the spot that represents your answer.

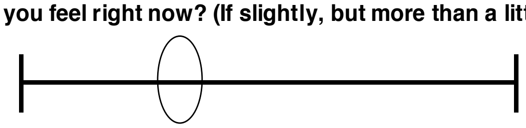
For example: CORRECT marking

How hungry do you feel right now? (If slightly, but more than a little, hungry.)

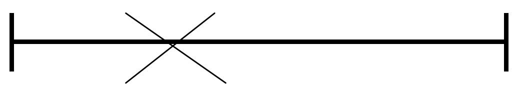
not at all a little somewhat very extremely

For example: INCORRECT markings

How hungry do you feel right now? (If slightly, but more than a little, hungry.)



not at all a little somewhat very extremely



not at all a little somewhat very extremely

not at all a little somewhat very extremely

Study#______________   MR#____________
Interval______________   Date____________

1. How hungry do you feel right now?

not at all   a little   somewhat   very   extremely

2, How full do you feel right now?

not at all   a little   somewhat   very   extremely

3. How much food do you think you could eat right now?

a very small amount   a little   a lot   a very large amount

4. I feel anxious.

not at all   a little   somewhat   very   <u>very</u> much

5. I feel sleepy.

not at all   a little   somewhat   very   <u>very</u> much

6. I feel sick.

not at all   a little   somewhat   very   <u>very</u> much

Study#______________ MR#____________
Interval______________ Date____________

7. I feel dizzy.

not at all **a little** **somewhat** **very** **<u>very</u> much**

8. My tummy is rumbling.

not at all **a little** **somewhat** **very** **<u>very</u> much**

9. My tummy feels upset.

not at all **a little** **somewhat** **very** **<u>very</u> much**

10. My head hurts. (I have a headache.)

not at all **a little** **somewhat** **very** **<u>very</u> much**

11. I feel thirsty.

not at all **a little** **somewhat** **very** **<u>very</u> much**

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